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POWERING CHARACTERISTICS OF SWATH-6A IN CALM WATER AND HEAD SEA--ETC(U)
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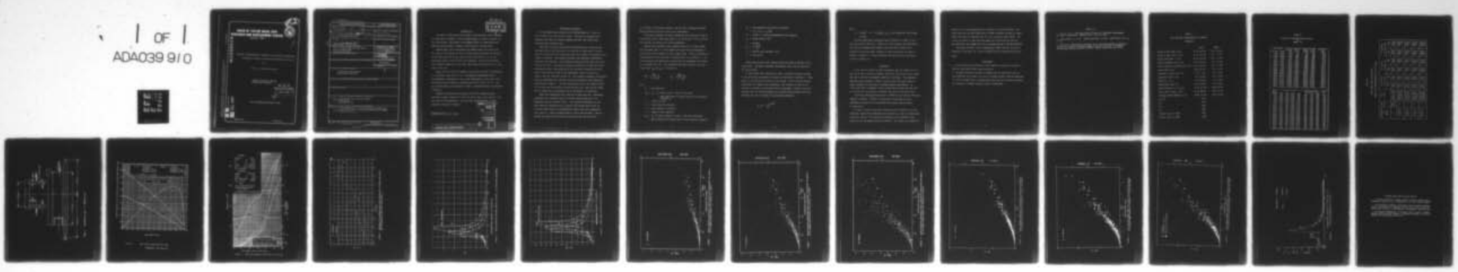

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

POWERING CHARACTERISTICS OF SWATH-6A IN CALM WATER AND HEAD SEAS

REPRESENTED BY MODEL 5337-A AND USING PROPELLERS 4415-4416

BY

HUGH Y. H. YEH AND EDDIE NEAL

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SMALL WATERPLANE AREA TWIN HULL SHIP (SWATH)
ADDED POWER IN WAVE
ADDED RESISTANCE IN WAVE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

POWERING CHARACTERISTICS OF A SWATH-6 SHIP WERE PREDICTED USING EXPERIMENTAL DATA. AVERAGE ADDED POWER REQUIREMENTS FOR VARIOUS SEA CONDITIONS ARE GIVEN.

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INTRODUCTION

The David W. Taylor Naval Ship Research and Development Center (DTNSRDC) has undertaken a program to find an optimum design of a small waterplane twin hull (SWATH) ship. This phase of the program centers on investigating the powering characteristics of SWATH in calm as well as in rough water.

DTNSRDC Model 5337-A representing the SWATH-6 design was selected for this phase of work because it has the largest clearance between the underside of the cross-structure and the water surface, and because it is the only SWATH model which has trim control fins (Canards). Both of these features are considered beneficial to the rough water powering characteristics of this type of hull form.

Model 5337-A was built of aluminum, balsa wood, styrofoam and fiberglass, to a ship-model scale ratio of 22.5. The demihull displacement used in the experiment corresponds to a full scale displacement of 1461 metric tons. The distance between demihull centerlines was set at 22.86 m (75 ft). The ship characteristics are tabulated in Table 1, abbreviated lines are presented in Figure 1.

DTNSRDC five bladed stock propellers 4415-4416, representing ship propellers having a diameter of 4.36 m (14.30 ft) with a pitch ratio of 1.147 were used for the experiments. The open water characteristics of these propellers are given in Figure 2.

References are listed on page 7.

EXPERIMENTS AND RESULTS

All experiments were conducted in the DTNSRDC Basin No. 2 which is 421.7 m long, 15.8 m wide and 6.7 m deep. This basin is equipped with a pneumatic wave maker, to generate regular (periodic) and long-crested uni-directional irregular waves.

Calm water resistance and propulsion experiments were conducted with the model free to pitch and heave but restricted in other modes of motion. Each hull was fitted with a towing post which was attached to the model at the center of flotation. The standard resistance and propulsion experimental procedures were followed. No turbulence stimulation devices were used; ITTC friction line with a correlation allowance coefficient of 0.0004 was used in analyzing the data. The prediction of the calm water resistance and propulsion characteristics based on the experimental results are given in Figure 3 and also tabulated in Table II. The residuary resistance coefficients from the experiments were compared with those predicted by using analytical calculations in Figure 4. The small differences seen in this figure account for the fact that the analytical predictions were for a ship without canard and in captive mode, the agreement can be considered to be excellent.

Rough water experiments were conducted for head seas only. Resistance experiments were conducted using the constant speed method due to its simplicity and more accurate results. The propulsion experiments on the other hand were conducted with an entirely free running model except for the power supply wires and instrumentation leads, which were suspended in such a way as to impose a minimum amount of force upon the model. Correct heading and speed are electronically controlled, thus the mean speed

of the model is practically constant, and the correct heading maintained. Model propulsion points were used in the experiments.

Both added resistance and power experiments were conducted in regular and irregular waves; three ship speeds, 5.14, 10.29 and 14.4 m/s or 10, 20, and 28 knots, were selected for these experiments.

Regular wave experiments were conducted using 12 to 15 wave lengths for each speed, and 2 to 3 wave heights were used for each wavelength to assure that the wave height was within linear range. (This is necessary for the application of the principle of superposition, see reference 1). The added resistance and added power obtained from the experiments was reduced to a nondimensional form. The nondimensional added resistance and power coefficients σ_{AW} and π_{AW}, are defined as:

$$\sigma_{AW} = \frac{R_{AW}}{\rho g \zeta_A^2 \frac{B^2}{L}} \quad ; \quad \pi_{AW} = \frac{P_{AW}}{\rho g \zeta_A^2 \frac{B^2}{L} V}$$

Where:

ζ_A = Wave amplitude

$P_{AW} = P_W - P_o$ = Power in wave - Power in calm water

= Mean added power in regular waves at wave encounter frequency μ_e

ρ = Density of water

g = Gravitational acceleration

B = Beam (diameter of demihull)

L = Length of body (demihull)

$R_{AW} = R_W - R_o$ Mean resistance in waves - Calm water resistance

= Added resistance in regular waves at wave encounter frequency

μ_e = Non-dimensional wave encounter frequency

= $\mu(1 + \mu F_n) = \omega_e \sqrt{L/g}$

μ = $\omega\sqrt{L/g}$ = Circular nondimensional wave frequency

F_n = Froude number, $V/\sqrt{gL}$

V = Velocity

ω_e = $\omega + \frac{\omega^2 V}{g}$

ω = Circular wave frequency, $2\pi/T$

T = Wave period

Added resistance and power response curves are given in Figures 5 and 6 respectively. The symbol represents the measured value, and the lines were the faired values.

To obtain mean added resistance or power, the above curves were applied to the particular sea spectrum in question as described in reference 2. Three groups of wave spectra were used for this purpose. One is the very spectrum used during the irregular wave experiments, this served as a check of the validity of response curve obtained from the experiment. Second, is the one commonly used, the Pierson-Moskowitz sea spectrum which represents the fully developed sea, and is defined by the following formulation

$$S_\zeta(\omega) = \frac{A}{\omega^5} e^{-B/\omega^4}$$

Where:

$A = 0.001g^2$; $B = 33.56/h^2_{1/3}$, $h_{1/3}$ is the significant wave height in feet.

The mean added power calculated using P-M spectra are added to calm water and shown in Table III. Third, for a more realistic sea description, the recently published North Atlantic Ocean Sea spectra (Miles 1972, reference 3) were also used. Results of these applications are shown in Figures 7 through 12. A typical spectrum obtained during the experiments is shown in Figure 13.

DISCUSSION

It was observed during the model experiments that the SWATH-6 as it is will not be able to operate throughout the entire speed range without canard. The trim of the ship is extremely sensitive to the speed. The calm-water powering curves presented in Figure 3 are for ship with canard angle of attack optimized at each speed for minimum powering requirements. In a full-scale ship an automatic control canard which can keep the ship level at all times will be required to operate this type of ship effectively.

Calm water powering characteristics of SWATH-6 do not show any advantage compared to SWATH-4. However, the selection of this model for this experiment was based on its anticipated better motion characteristics in rough water.

In order to obtain rough water predictions for the SWATH-6 in all sea conditions, regular wave experiments were conducted to obtain the added power coefficient curves. To ascertain the validity of the experimental data irregular wave experiments were also conducted. The results are compared in

Figure 12; its close agreement gives confidence to the data obtained. The added resistance and power predicted for SWATH-6 compares favorably at higher speed with those of a monohull, but it is not as good at lower speeds. The crux of the matter is that the added powers are the function not only of the significant wave height but also of the modal period of the wave spectrum.

Percentage increase of SHP is consistently higher than the increase in resistance, (See Table II). This also agrees with the finding for mono-hull ships.

CONCLUSIONS

1. The calm water characteristics of this SWATH-6 is found to be similar to those of other SWATH models tested previously.
2. The added resistance and power of SWATH-6 are the function not only of the significant wave height, but also of the modal period of the wave spectrum.
3. Since the added power is consistently higher than the increased resistance the evaluation of SWATH-6 should be based on added power.

REFERENCES

1. Yeh, H. et al., "Powering Characteristics of a Low Block Displacement Hull Form in Head Seas," DTNSRDC Report 4089 (Jun 1975).

2. Strom-Tejsen, J. et al., "Added Resistance in Waves," SNAME Trans. Vol. 81, (1973).

3. Miles, M., "Wave Spectra Estimated from a Stratified Sample of 323 North Atlantic Wave Records," National Research Council, Division of Mechanical Engineering, Ottawa, Laboratory Technical Report LTR-SH-118A (May 1972).

TABLE 1

SHIP AND MODEL CHARACTERISTICS OF SWATH-6

(DEMIHULL)

	SHIP	MODEL
LENGTH OF BODY (LOA) m (ft)	74.20 (243.45)	3.30 (10.82)
LENGTH OF STRUT (LWL) m (ft)	53.13 (174.31)	2.36 (7.75)
LENGTH (EFFECTIVE) m (ft)	68.52 (224.80)	3.04 (9.99)
LENGTH (ENTRANCE) (L_E) m (ft)	13.17 (43.20)	.58 (1.92)
LENGTH (PARALLEL MID-BODY)(L_X) m (ft)	40.43 (132.66)	1.80 (5.90)
LENGTH (RUN) m (ft)	20.60 (67.59)	.92 (2.87)
THICKNESS AT STRUT (B) m (ft)	2.21 (7.25)	.10 (0.32)
DIAMETER OF BODY m (ft)	4.57 (15.00)	.20 (0.67)
DRAFT (T) m (ft)	8.13 (26.66)	.36 (1.18)
DISPLACEMENT TONNE (LT)	14.61 (14.38)	.125 (.123)
WETTED SURFACE sq. m. (sq ft)	14.24 (15,324)	2.813 (30.27)
LONG'L RAD. OF GYNA. m (ft)	18.55 (60.86)	.824 (2.70)
DISTANCE BETWEEN DEMIHULL m (ft)	22.86 (75.00)	1.016 (3.333)
C_P BODY	.8512	
C_{PG}	.6991	
C_{PR}	.6564	
C_W	.8178	
LCB/LWL from L.E. STRUT	.6054	
LCF/LWL from L.E. STRUT	.5005	

TABLE II

Calm Water Powering Characteristics
for
SWATH - 6A

SHIP SPEED (KNOTS)	SHIP SPEED (M/SEC)	EFFECTIVE POWER (PE) (HORSE-POWER)	EFFECTIVE POWER (PE) (KILO-WATTS)	SHAFT POWER (PS) (HORSE-POWER)	SHAFT POWER (PS) (KILO-WATTS)	REVOLUTIONS PER MINUTE
4.0	2.06	50.	35.	75.	55.	25.5
5.0	2.57	125.	90.	180.	135.	32.0
6.0	3.09	210.	155.	305.	225.	39.0
7.0	3.60	355.	265.	500.	375.	47.0
8.0	4.12	810.	605.	1120.	830.	56.4
9.0	4.63	1170.	870.	1580.	1180.	66.8
10.0	5.14	1620.	1210.	2170.	1620.	77.0
11.0	5.66	2260.	1680.	3030.	2260.	88.5
12.0	6.17	3210.	2390.	4330.	3230.	98.1
13.0	6.69	4200.	3130.	5600.	4180.	106.5
14.0	7.20	5050.	3770.	6600.	4920.	114.3
15.0	7.72	5560.	4150.	7170.	5350.	118.1
16.0	8.23	6000.	4470.	7690.	5740.	119.7
17.0	8.75	6700.	5000.	8610.	6420.	124.8
18.0	9.26	7800.	5810.	10110.	7540.	131.5
19.0	9.77	9400.	7010.	12340.	9200.	140.2
20.0	10.29	11850.	8840.	16010.	11940.	149.2
21.0	10.80	15080.	11250.	21010.	15660.	162.0
22.0	11.32	18540.	13830.	26190.	19530.	175.5
23.0	11.83	21980.	16390.	30960.	23090.	186.4
24.0	12.35	24930.	18590.	34870.	26000.	196.5
25.0	12.86	27410.	20440.	38070.	28390.	205.0
26.0	13.38	29930.	22320.	41220.	30740.	212.4
27.0	13.89	31990.	23850.	43820.	32670.	219.5
28.0	14.40	33830.	25230.	46030.	34320.	224.4

SHIP SPEED (KNOTS)	EFFICIENCIES (ETA) ETAD	ETAO	ETAH	ETAR	THRUST DEDUCTION AND WAKE FACTORS 1-T	1-WT	1-WQ	ADVANCE COEF. JT
4.0	.674	.637	1.181	.896	.910	.770	.730	.856
5.0	.693	.617	1.284	.862	.906	.705	.629	.781
6.0	.695	.622	1.236	.904	.903	.731	.683	.796
7.0	.707	.623	1.190	.954	.902	.758	.737	.800
8.0	.724	.553	1.381	.948	.899	.651	.612	.654
9.0	.737	.582	1.223	1.035	.900	.736	.758	.702
10.0	.746	.598	1.133	1.101	.903	.797	.854	.733
11.0	.744	.606	1.064	1.153	.910	.855	.933	.753
12.0	.740	.596	1.082	1.148	.910	.841	.925	.729
13.0	.750	.593	1.098	1.157	.911	.830	.921	.717
14.0	.755	.598	1.083	1.182	.914	.844	.941	.733
15.0	.775	.605	1.099	1.166	.915	.832	.914	.749
16.0	.790	.608	1.147	1.119	.915	.798	.856	.756
17.0	.778	.612	1.146	1.109	.911	.795	.846	.767
18.0	.771	.613	1.146	1.097	.910	.794	.840	.770
19.0	.752	.613	1.136	1.095	.910	.801	.846	.769
20.0	.740	.604	1.159	1.058	.910	.785	.818	.746
21.0	.718	.594	1.128	1.072	.890	.789	.832	.725
22.0	.708	.598	1.099	1.078	.907	.825	.872	.733
23.0	.710	.601	1.093	1.091	.925	.846	.894	.740
24.0	.715	.607	1.076	1.094	.938	.871	.924	.754
25.0	.720	.612	1.059	1.111	.940	.888	.945	.767
26.0	.726	.615	1.051	1.124	.940	.895	.955	.776
27.0	.730	.619	1.037	1.137	.937	.904	.966	.788
28.0	.735	.621	1.034	1.145	.928	.898	.960	.793

TABLE III

MEAN ADDED POWER FOR SWATH-6A

BASED ON PIERSON-MOSKOWITZ SEA SPECTRUM

SIGNIFICANT WAVE HEIGHT	SEA STATE	SHIP SPEED	10.0 Knots 5.144 m/s		20.0 Knots 10.289 m/s		28.0 Knots 14.404 m/s	
			EHP	SHP	EHP	SHP	EHP	SHP
0	CALM WATER	HORSEPOWER KILOWATTS	1620 1210	2170 1620	11850 8840	16015 11940	33830 25230	46030 34325
6.900 ft 2.103 m	4	HORSEPOWER KILOWATTS INCREASE %	1675 1250 3.4	2330 1738 7.3	11950 8910 0.9	16290 12150 1.7	34005 25360 0.5	46460 34645 0.9
10.000 ft 3.048 m	5	HORSEPOWER KILOWATTS INCREASE %	1830 1365 13.2	2780 2075 28.0	12270 9150 3.5	17080 12740 6.6	34585 25790 2.2	47610 35500 3.4
15.000 ft 4.572 m	6	HORSEPOWER KILOWATTS INCREASE %	2190 1635 35.3	3870 2885 78.2	13065 9740 10.2	19070 14220 19.1	35950 26810 6.2	50035 37310 8.7
30.000 ft 9.144 m	7	HORSEPOWER KILOWATTS INCREASE %	3120 2330 92.6	7260 5415 334.5	15070 11240 27.2	24415 18210 52.4	38995 29080 15.2	55950 41720 21.6

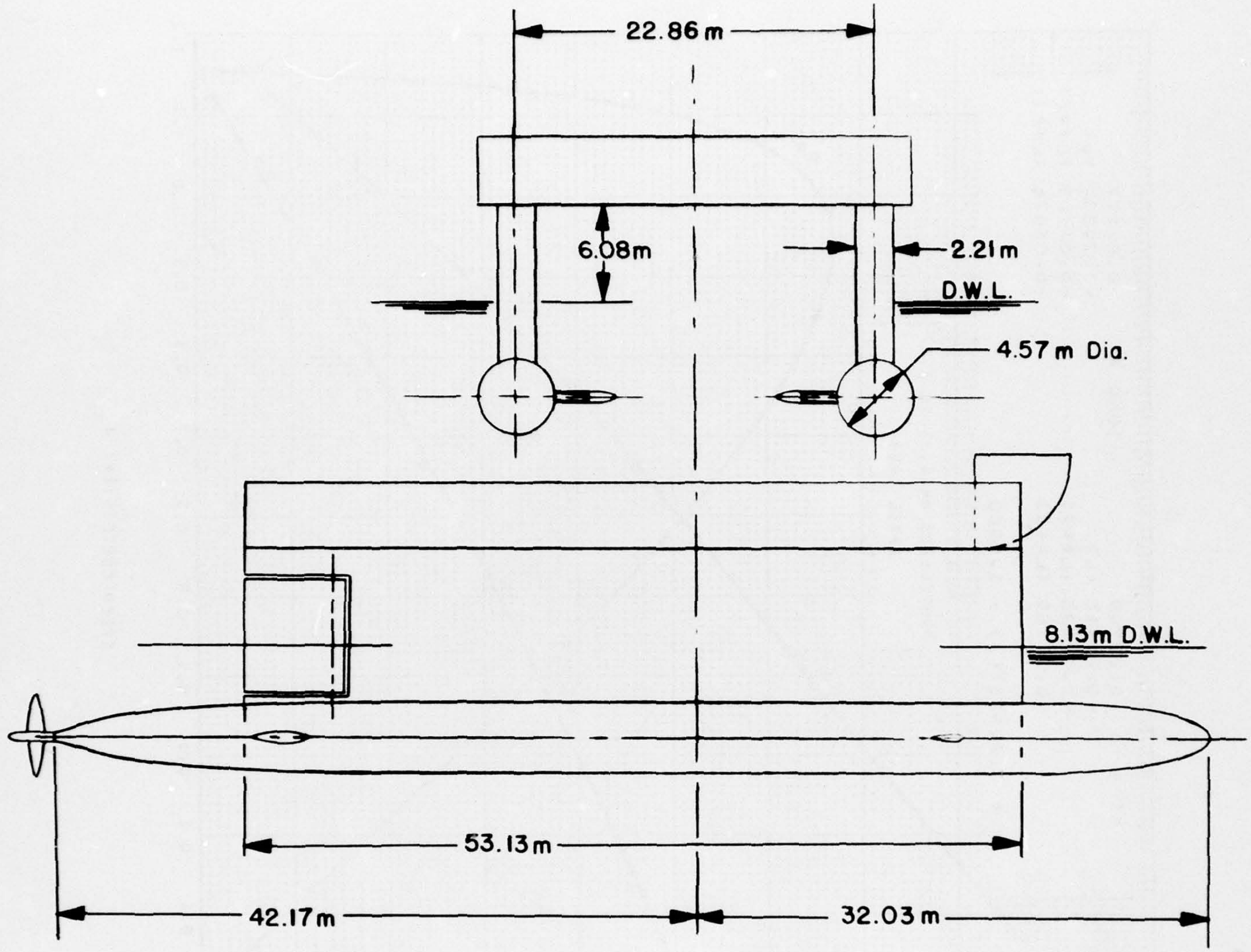

Figure 1. Abbreviated Lines of SWATH-6A

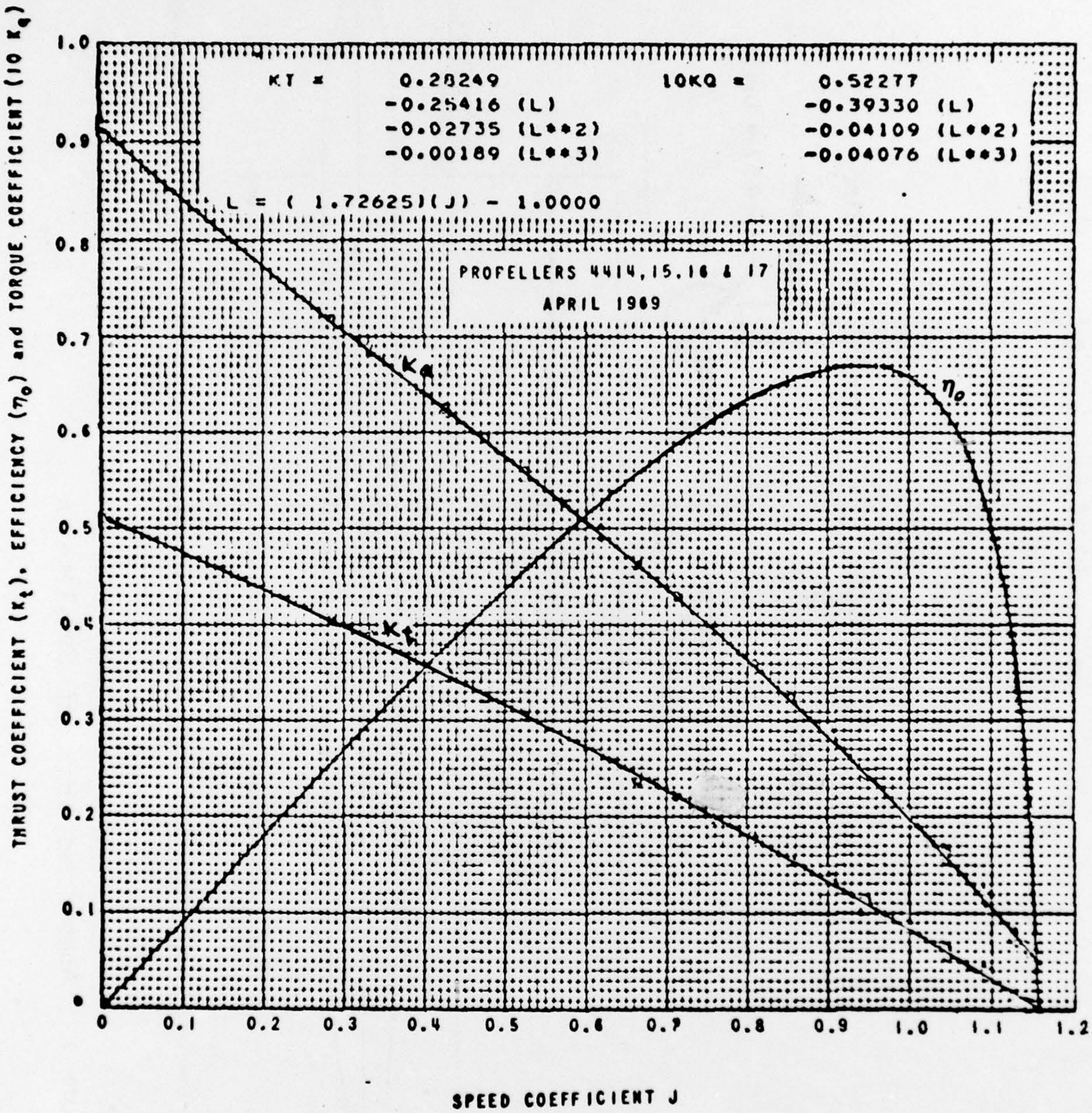

FIGURE 2 OPEN WATER CHARACTERISTICS CURVE

PROPELLERS 4416 and 4417

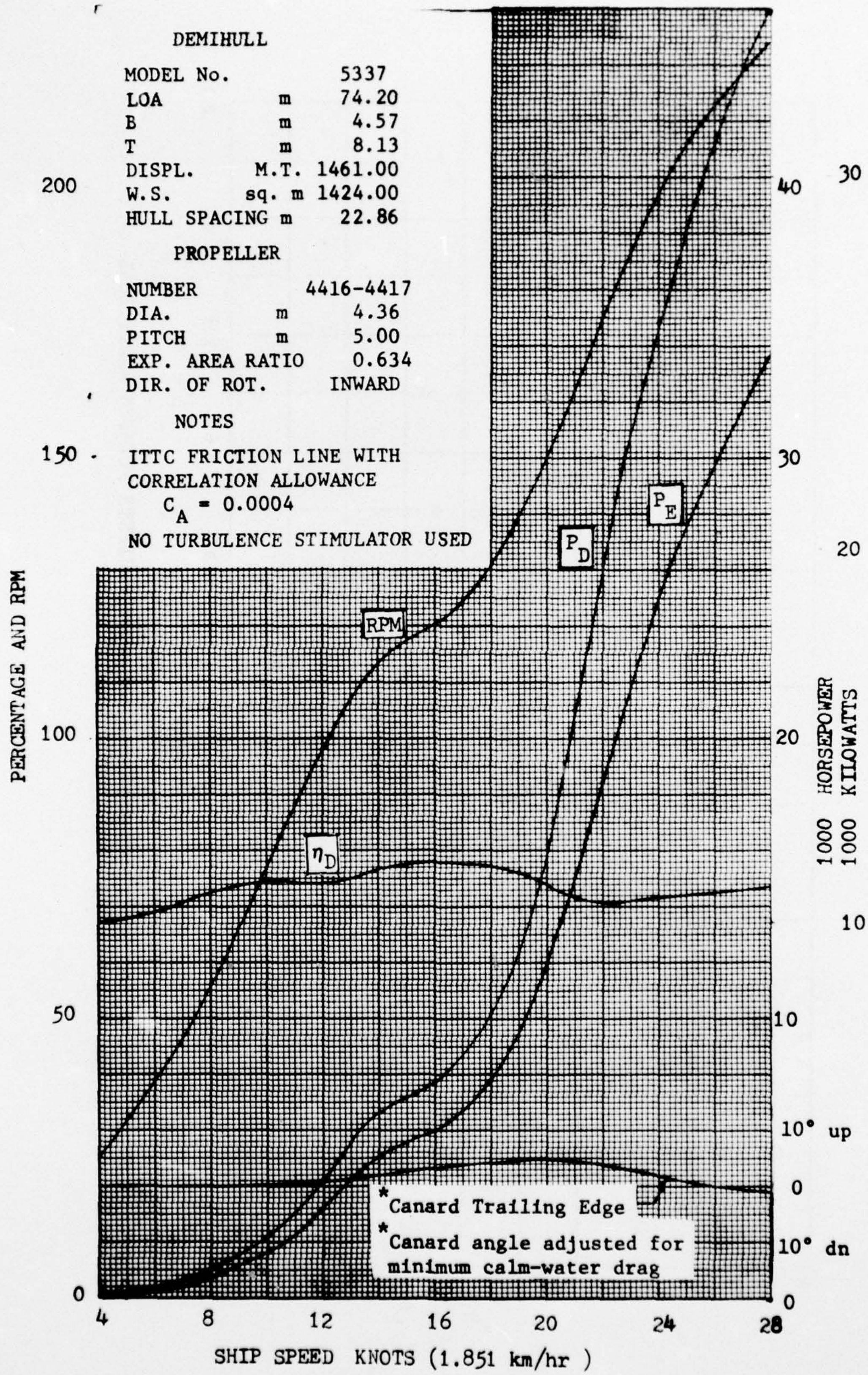

FIGURE 3 CALM WATER POWER AND RPM CURVES FOR SWATH-6A

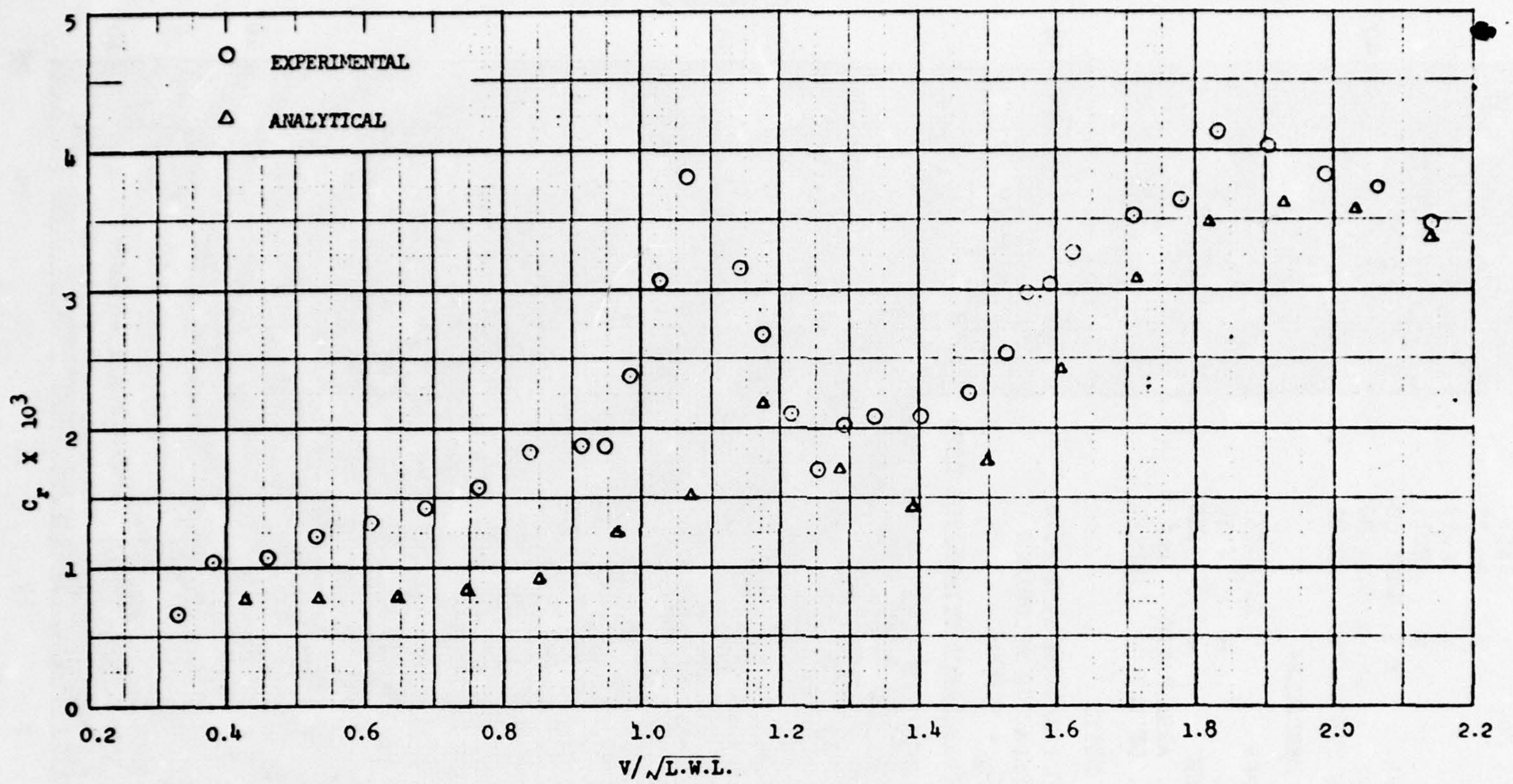

FIGURE 4 COMPARISON OF RESIDUARY RESISTANCE COEFFICIENTS BETWEEN ANALYTICAL AND EXPERIMENTAL PREDICTIONS FOR SWATH-6A

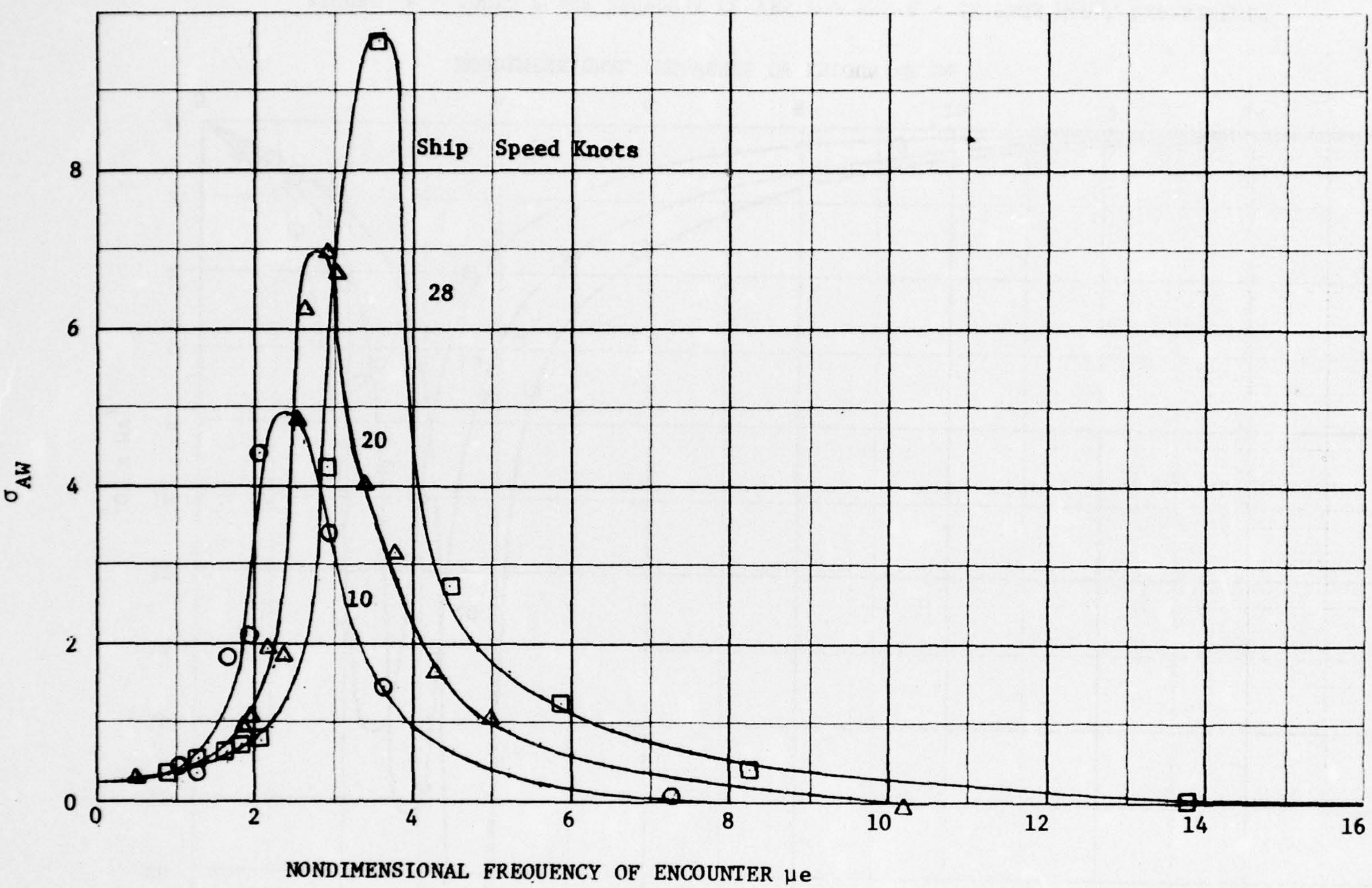

FIGURE 5 - ADDED RESISTANCE RESPONSE CURVES FOR SWATH - 6A FROM MODEL EXPERIMENTS

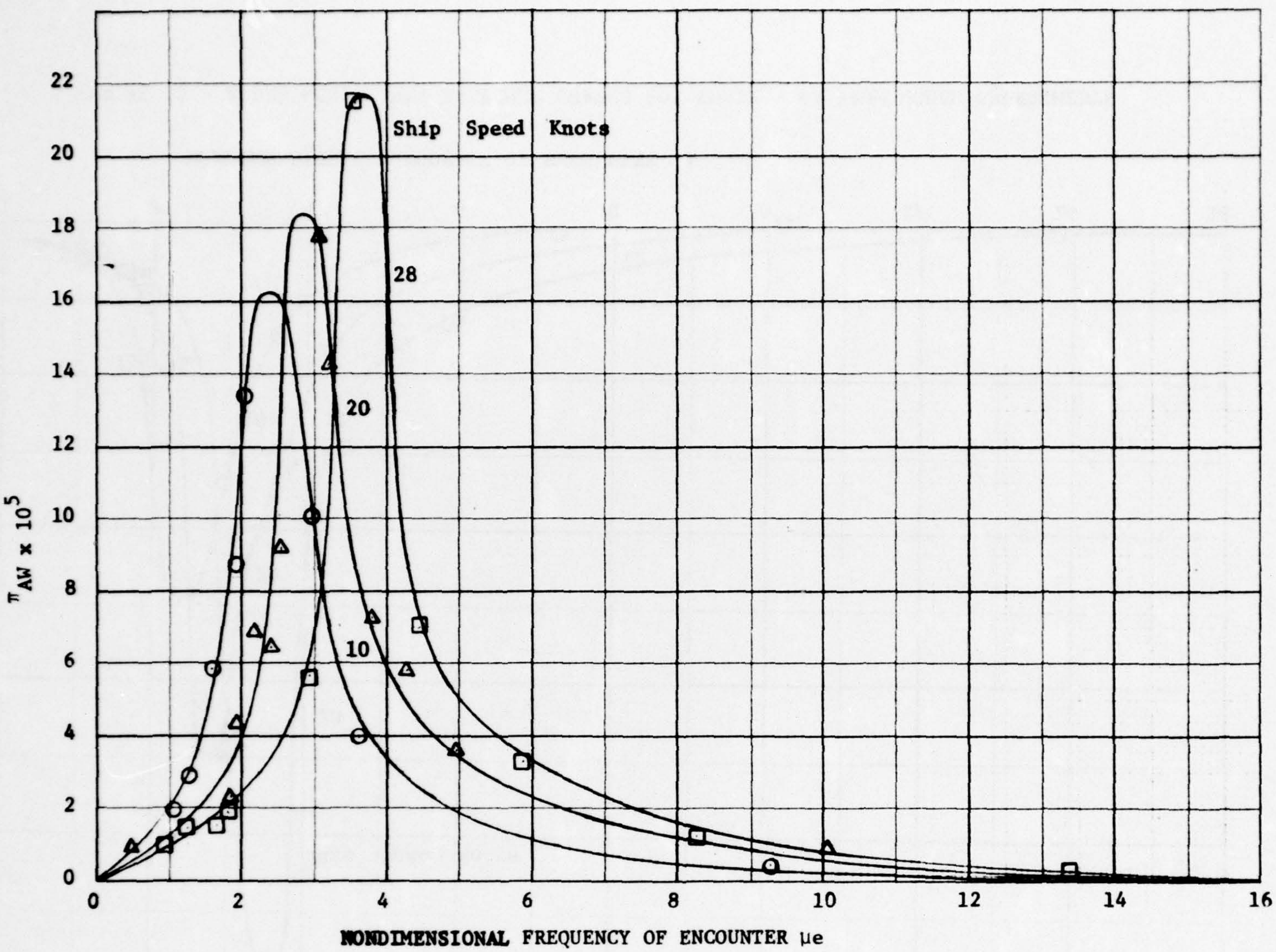

FIGURE 6 - ADDED POWER RESPONSE CURVES FOR SWATH - 6A FROM MODEL EXPERIMENTS

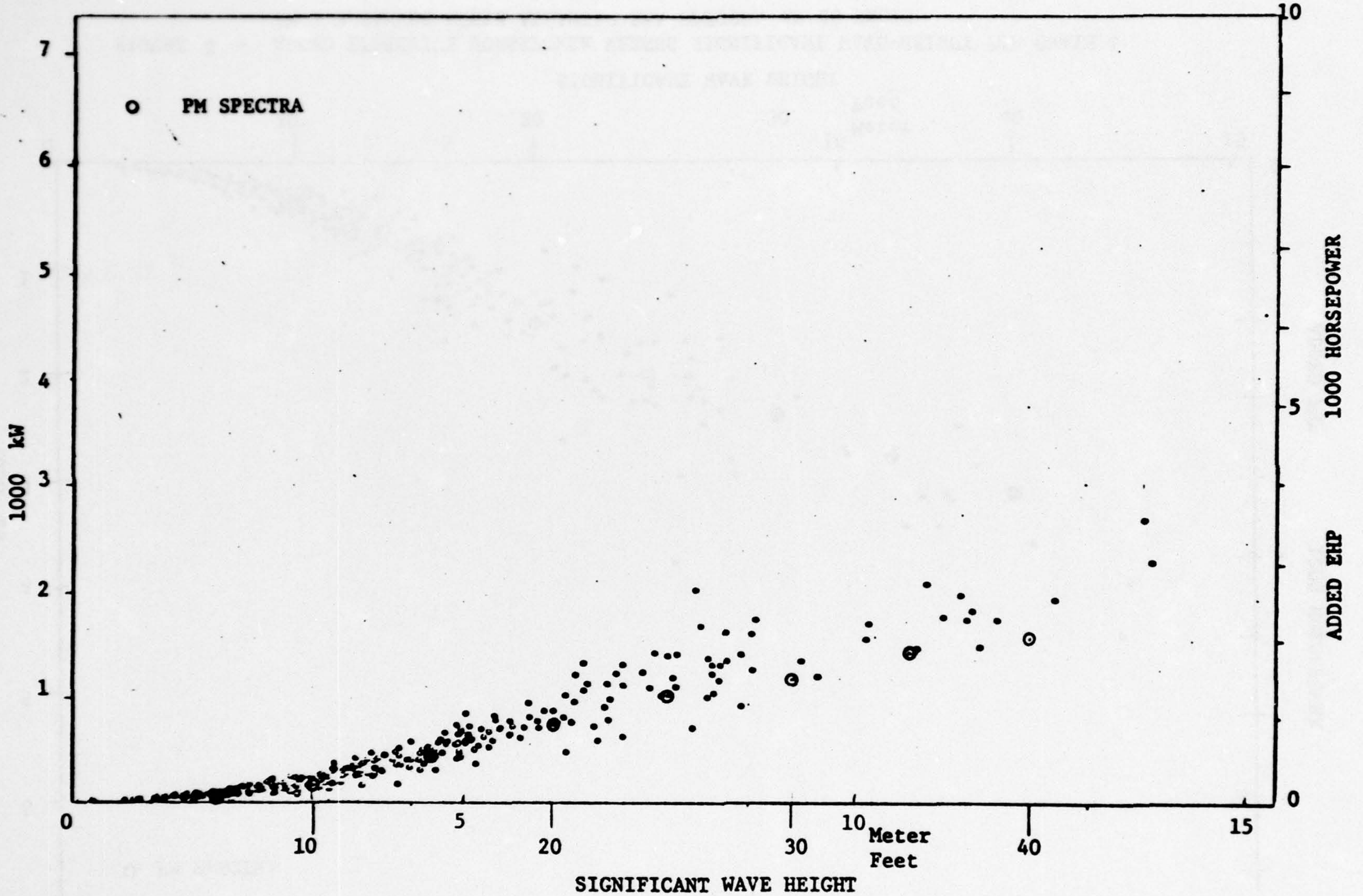

FIGURE 7 - ADDED EFFECTIVE HORSEPOWER VERSUS SIGNIFICANT WAVE-HEIGHT FOR SWATH-6 IN 323 SAMPLE NORTH ATLANTIC SEA SPECTRA AT 10 KNOTS

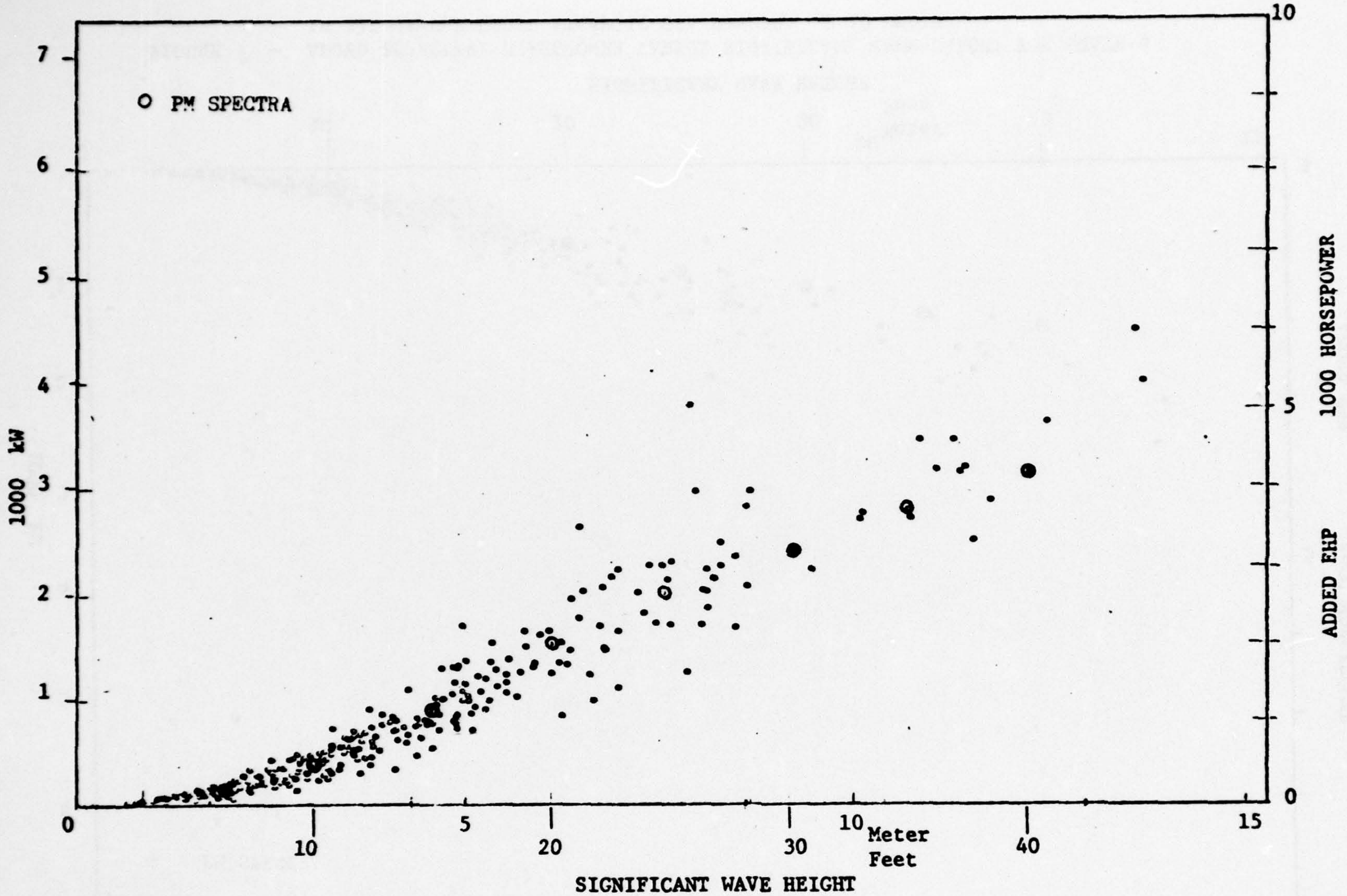

FIGURE 8 - ADDED EFFECTIVE HORSEPOWER VERSUS SIGNIFICANT WAVE-HEIGHT FOR SWATH 6 IN 323 SAMPLE NORTH ATLANTIC SEA SPECTRA AT 20 KNOTS

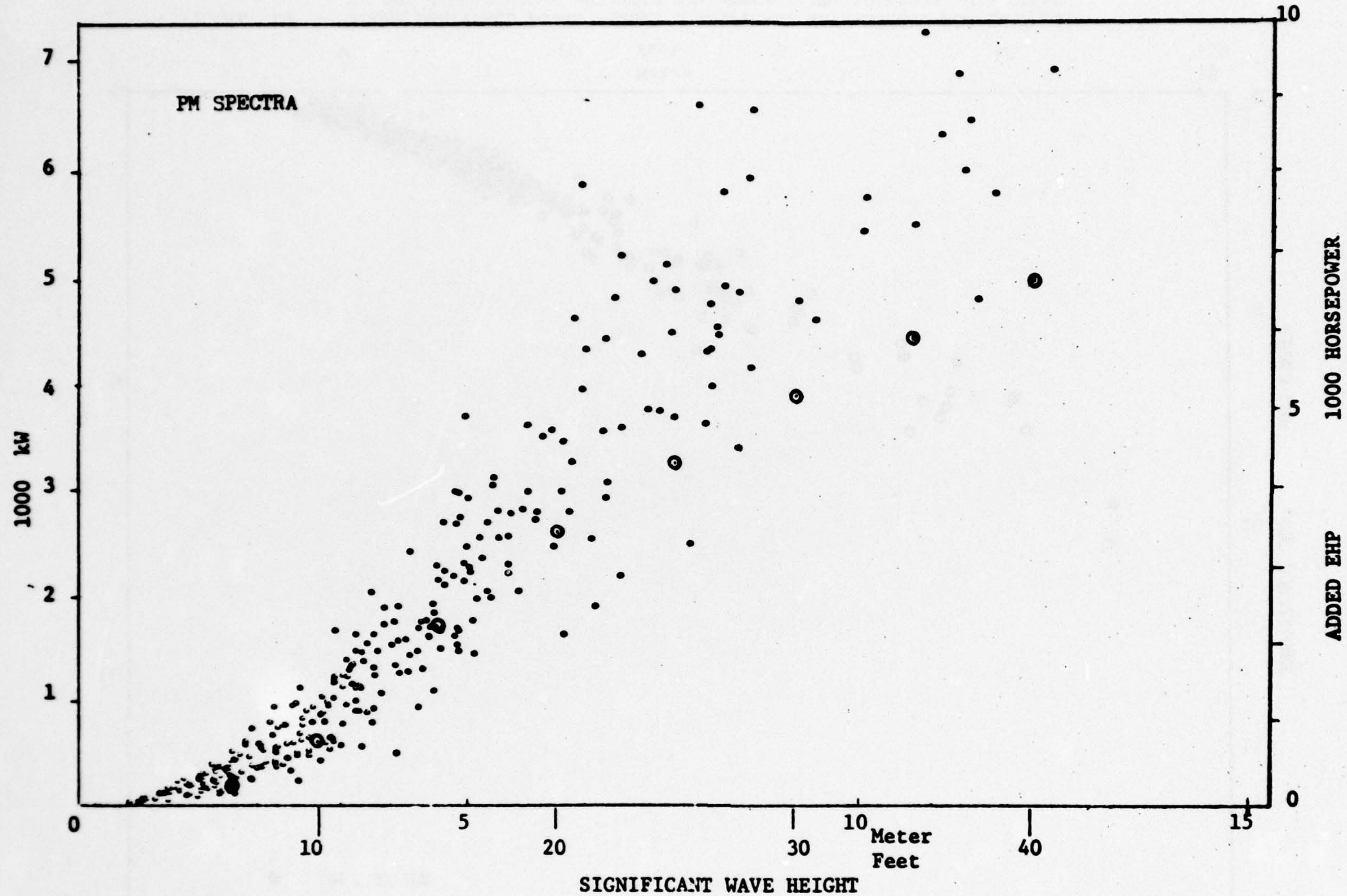

FIGURE 9 - ADDED EFFECTIVE HORSEPOWER VERSUS SIGNIFICANT WAVE-HEIGHT FOR SWATH 6 IN 323 SAMPLE NORTH ATLANTIC SEA SPECTRA AT 28 KNOTS

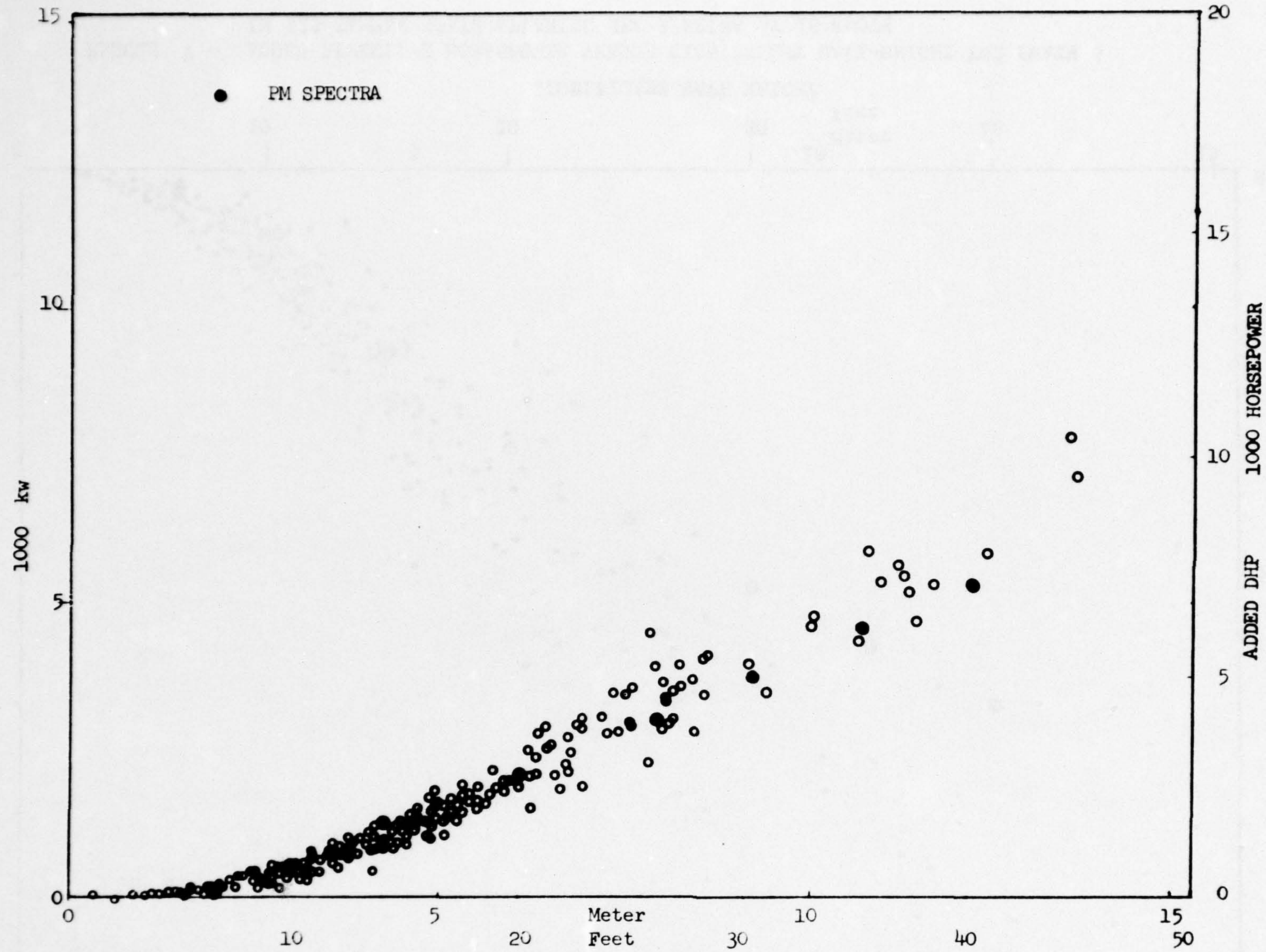

FIGURE 10 - ADDED DELIVERED POWER VERSUS SIGNIFICANT WAVE-HEIGHT FOR SWATH-6A IN 323 SAMPLE NORTH ATLANTIC SEA SPECTRA AT 10 KNOTS SHIP SPEED.

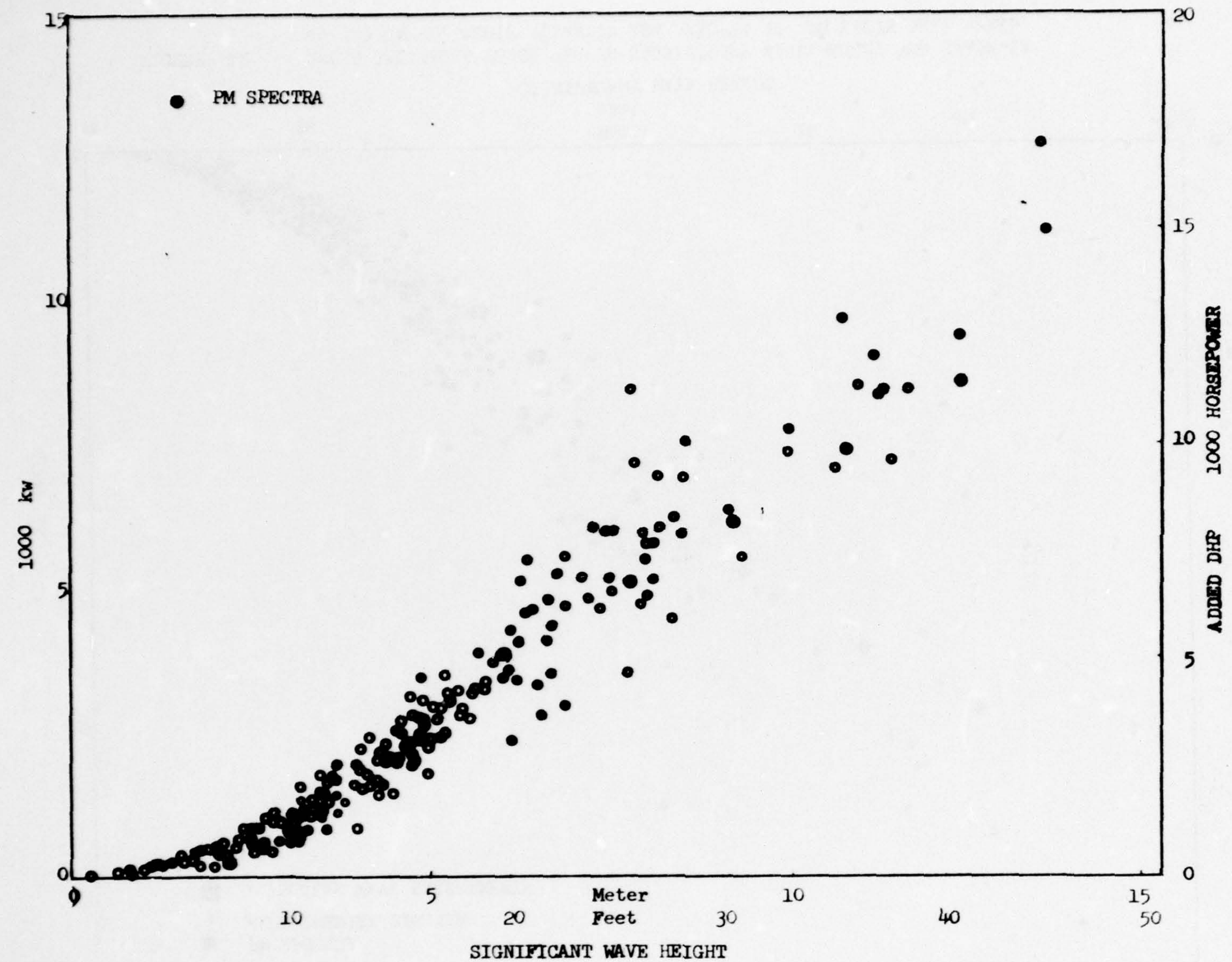

FIGURE 11 - ADDED DELIVERED POWER VERSUS SIGNIFICANT WAVE-HEIGHT FOR SWATH-6A IN 323 SAMPLE NORTH ATLANTIC SEA SPECTRA AT 20 KNOTS SHIP SPEED.

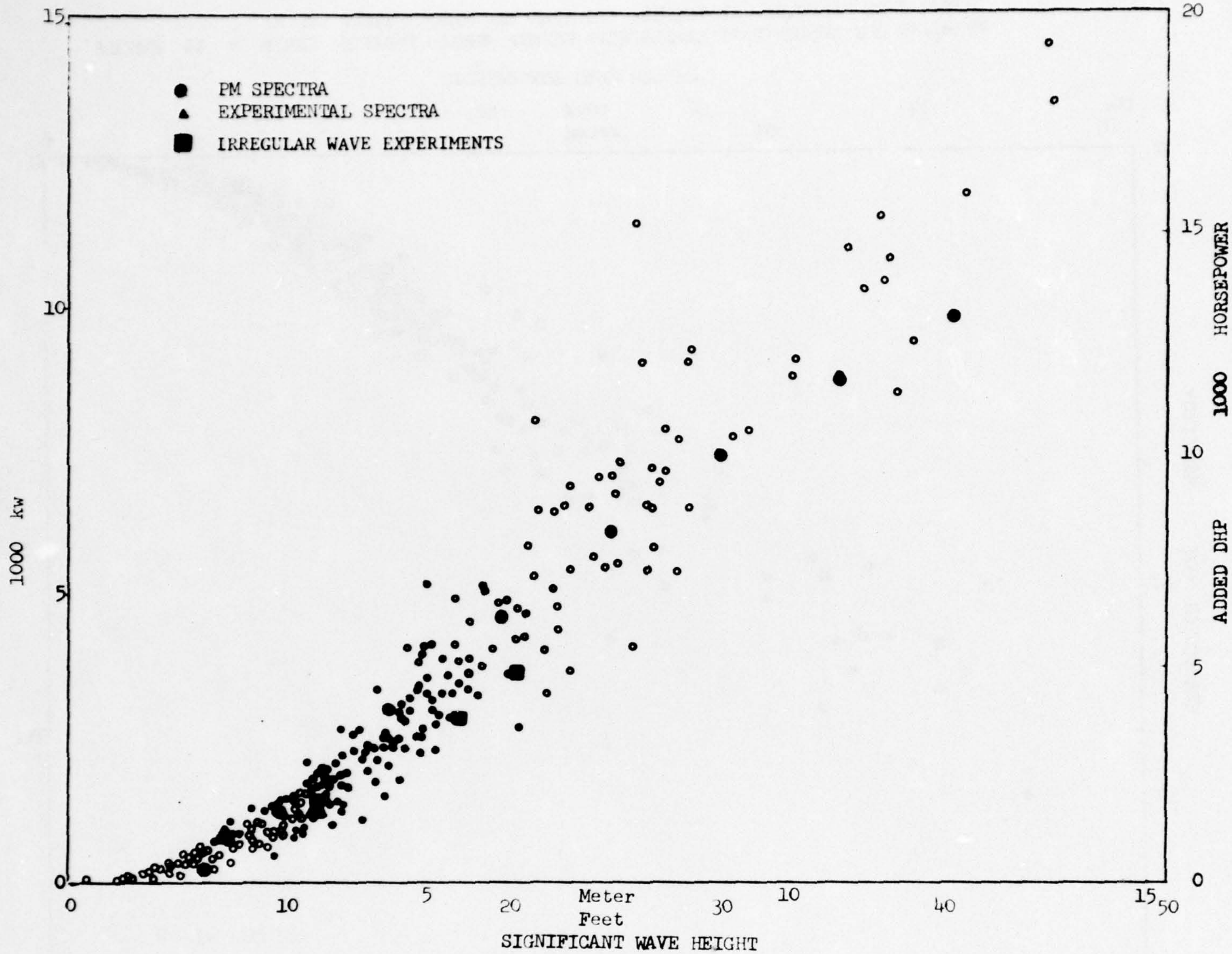

FIGURE 12 - ADDED DELIVERED POWER VERSUS SIGNIFICANT WAVE-HEIGHT FOR SWATH-6A IN 323 SAMPLE NORTH ATLANTIC SEA SPECTRA AT 28 KNOTS SHIP SPEED.

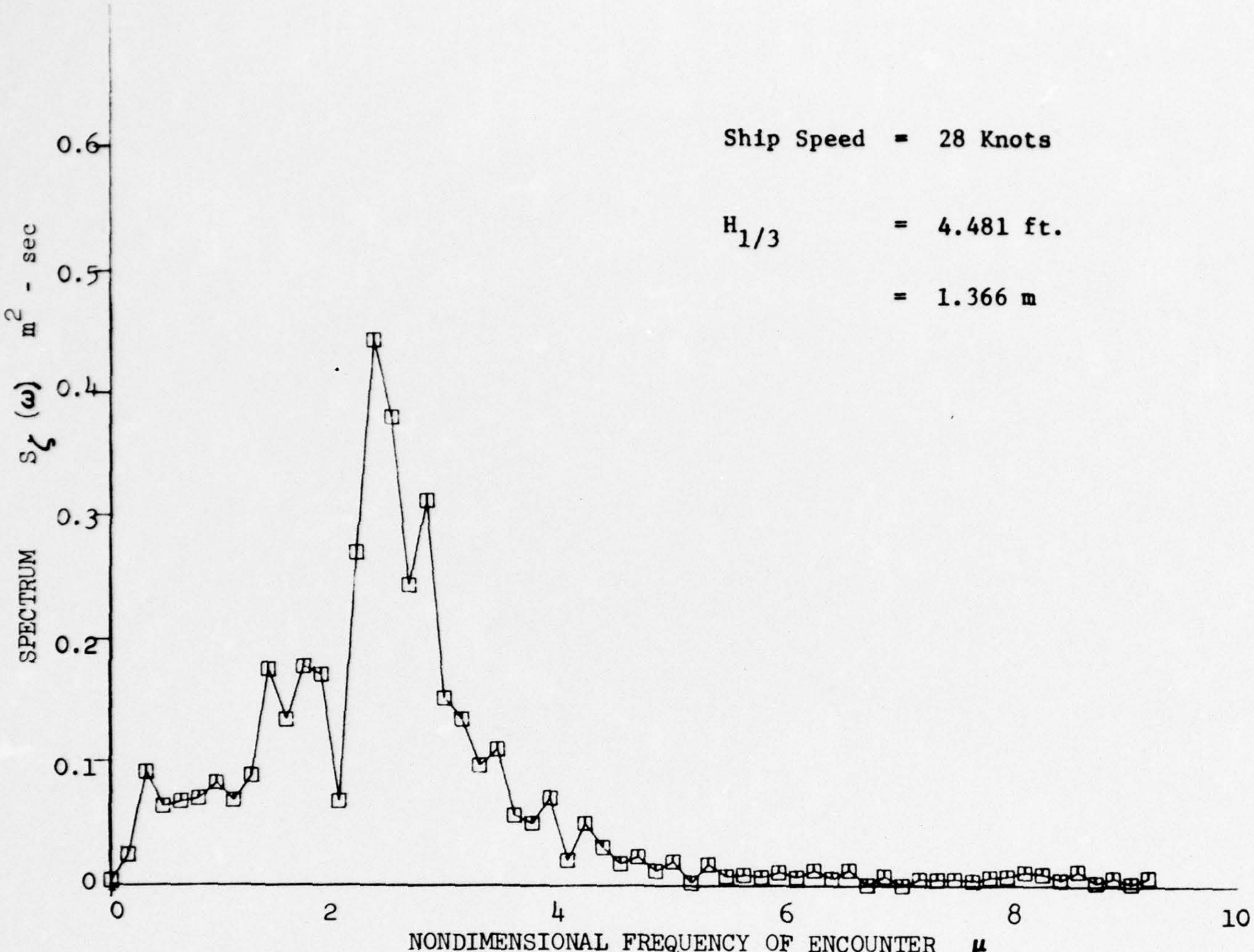

FIGURE 13 TYPICAL EXPERIMENTAL WAVE SPECTRUM

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